CHARACTERIZING CENTER OF MASS AND MOMENT OF INERTIA OF SOLDIERS' LOADS PACKED FOR COMBAT

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ABSTRACT

The purpose of this study was to characterize loads packed by Soldiers preparing for deployment and to determine the degree to which center of mass (COM) location and moment of inertia (MOI) may be influenced in combat load packing. In addition, the physical properties of the combat loads were compared to the properties of a laboratory fabricated backpack. Field measurements of mass, COM, and MOI were made on All-purpose Lightweight Individual Carrying Equipment (ALICE) rucksacks of 50 Soldiers (11 from an Airborne Division, and 39 from a Light Infantry Division). Results indicate that previous laboratory measurements did not capture the full range of COM and MOI values represented among Soldier-packed combat loads. The COMs of the combat loads are located further away from the Soldier's back relative to a fabricated backpack used in the laboratory to study physical properties of loads. The range of the MOIs of the combat loads (Airborne: 0.302 kg·m^2 – 1.979 kg·m^2; Light Infantry: 0.143 kg·m^2 – 1.811 kg·m^2) was larger than the fabricated backpack (0.431 kg·m^2 – 0.882 kg·m^2). This study was an initial step in characterizing Soldiers' combat loads. Measurements of the physical properties of the Modular Lightweight Load-bearing Equipment (MOLLE) are needed to further characterize Soldiers' combat loads. Soldiers are required to perform many actions that involve linear and angular accelerations while carrying backpack loads. Optimizing load carriage will improve the efficiency of overground movements of Soldiers carrying loads and the fitness to fight of dismounted troops, thereby positively impacting the Future Force Warrior's ability to be responsive, agile, versatile, lethal, survivable, and easily sustainable.

1. INTRODUCTION

When considering linear motion, the mass of a body is the inertial property representing the resistance to linear acceleration. However, when rotary motion is involved, mass as well as how that mass is distributed about a particular axis of rotation must be considered (Martin et al., 1982). The moment of inertia (MOI) of a body describes the distribution of mass about a specified axis of rotation and, therefore, is the inertial property that represents a body's resistance to angular acceleration.

In the field, Soldiers are required to perform many actions that involve quick changes in angular motion, such as a sudden change of direction while running and "hitting the dirt." The additional mass and moment of inertia of Soldiers' backpacks will affect their ability to perform these actions as intended, quickly and in a controlled manner. As the mass and moment of inertia of the backpack increase about a given axis, the ability of the Soldier to initiate a change in angular motion about that axis becomes more difficult. Similarly, ceasing that movement once started is difficult. Therefore, a backpack with a reduced mass and a small moment of inertia is desired, and one with a large mass and moment of inertia is contraindicated (Hinrichs et al., 1982).

As stated, Soldiers are required to perform many actions that involve quick changes in angular motion. Primarily these actions require angular motion about the z-axis (longitudinal axis), such as a change of direction while running, and about the y-axis (medial-lateral axis), such as "hitting the dirt" (Hinrichs et al., 1982). Therefore, having small MOI values about these two principal axes is more critical than about the x-axis (anterior-posterior axis). However, it is undesirable for the MOI about the y- or the z-axis to be the intermediate moment of inertia, where its magnitude lies between those of the other two principal moments of inertia. This is because a small disturbance in angular velocity tends to grow if it is applied to a body that is rotating about the principal axis corresponding to the intermediate moment of inertia (Greenwood, 1965). Therefore, rotation about this axis is unstable, and the body will tend to rotate about the other two axes as well, which may make it difficult to control the rotation.

In previous laboratory projects, it was found that positioning the center of mass (COM) of a pack high and close to the load-carrier's back and keeping the MOI of the pack as small as possible minimizes the energy expended in carrying the load and improves stability of the load carrier (Norton et al., 2003; Obusek et al., 1997). In these studies, a custom external-frame backpack was fabricated, using as the frame the US Army's All-Purpose Lightweight Individual Carrying Equipment (ALICE). The backpack was designed to permit a weight, a 24.9-kg lead brick, to be placed in any one of 9 different locations within the pack. The total mass of the pack and the lead weight in it was 35 kg. The backpack was intended to exemplify the possible COM locations of a Soldier's backpack load while in the field, and the

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mass of the pack was intended to mimic the maximum approach load, as described in Field Manual 21-18 (Department of the Army, 1990).

The ability of Soldiers to perform physical activities while carrying backpack loads is important for the success of military operations. The locations in which items are placed within the pack may influence the ease of carrying the load. However, how Soldiers actually pack loads and the resulting physical properties of those loads (i.e., COM and MOI) remain relatively unknown. We conducted a study in which we gathered data in the field on the COM and MOI of backpack loads packed by Soldiers preparing for deployment. One purpose of the study was to document the mass, COM, and MOI of Soldier-packed loads. A second purpose was to determine whether the inertial properties of the backpack load fabricated by Obusek et al. (1997) for use in laboratory studies were similar to the properties of backpacks packed by and carried in the field by Soldiers.

In this paper, the physical properties of the field and the laboratory configured packs are compared and it is recommended that future laboratory packs be reflective of the field conditions. Optimizing load carriage will improve the efficiency of overground movements of Soldiers carrying loads and the fitness to fight of dismounted troops, thereby positively impacting the Future Force Warrior’s ability to be responsive, agile, versatile, lethal, survivable, and easily sustainable.

2. METHODS

We made measurements of mass, COM, and MOI on All-purpose Lightweight Individual Carrying Equipment (ALICE) rucksacks of 50 Soldiers (11 from an Airborne Division, and 39 from a Light Infantry Division). The data were collected on site at the units’ home stations. The packs were loaded by individual Soldiers with all equipment required in preparation for their immediate deployment to a combat area. Squad positions represented included: squad and team leaders, riflemen, mortarmen, heavy gunners, grenadiers, machine gunners and AGs, SAW gunners, sharp shooters, RTO’s, and mortar crews. We made identical measurements of the inertial properties of the custom backpack fabricated by Obusek et al. (1997) for the laboratory testing of effects of load location on energy cost. This pack was measured nine times. Each time, the load was placed in a different one of the 9 locations within the pack. The measurement procedures and equipment we used for determining the COM and the MOI are described in the following subsections.

2.1 Backpack System

The backpacks used by the Soldiers included the large pack and frame of the ALICE. The majority of the men also carried various models of assault packs from various manufacturers. The assault pack was secured at the top of the ALICE frame and laid over the ALICE pack. Other items were secured to the outside surfaces of the pack (Figure 1).

Fig. 1. Side and rear views of a backpack load, with assault pack attached to the frame at top and mortar base plate secured to ALICE pack.

2.2 Backpack Holder

A custom made aluminum holder was designed to stabilize the backpack while its mass properties were being measured. The holder was based on a previously designed aluminum holder that was used to stabilize an ALICE rucksack and frame (Hinrichs et al., 1982). The backpack was firmly fixed to the rear end of the holder for all load measurements. Figure 2 shows the backpack inside its aluminum holder. The rear left corner of the holder was defined as the reference corner, and a set of three orthogonal coordinate axes was defined relative to that corner. The x-axis is oriented from front to back, the y-axis from left to right, and the z-axis from bottom to top.

Fig. 2. ALICE pack firmly fixed to the rear of the holder and set in place on the force plate for a COM measurement.

2.3 Mass

A force plate (Model OR6-5, AMTI, Watertown, MA) was used to measure the mass of the holder, the backpack, and the composite (i.e., the holder with the backpack in place). The dimensions of the force plate are 0.508 meters along the y-axis and 0.464 meters along the x-axis. Mass was measured to the nearest thousandth of a kilogram.

2.4 Center of Mass

Force and moment data were measured and collected using the force plate interfaced with a computer-based data acquisition system. The data acquisition system consisted of a laptop computer with LabVIEW 6i (National Instruments, Austin, TX, USA) and a data acquisition card (National Instruments). The voltage output from the force plate was sampled at 1000 Hz. LabVIEW was used to collect, display, and analyze the force plate data.

For each measurement, we placed a pack on the plate and collected raw data for one second (1000 ms). Center of pressure (COP) for both x and y coordinates was computed from the raw force and moment data at each 1-millisecond interval and then averaged across the 1000 ms. Averaging the data over the 1000-ms window aided in reducing the noise on the COP measurement. For static objects, on a horizontal surface, the line of gravity (COP) passes through the center of mass of the object. Hence, we refer to the COP of the object as the center of mass (COM) of the test part.

A custom aluminum interface plate, which consisted of a matrix of precision-drilled holes 2 cm on center, was placed on the force plate to allow for the accurate measurement of the COM locations. The dimensions of the interface plate were the same as those of the force plate, 0.508 meters along the y-axis and 0.464 meters along the x-axis, and the mass of the interface plate was 8.12 kg. The COMs of the holder and of the composite (i.e., the holder and the backpack) relative to the reference corner of the holder were determined, which then allowed for the calculation of the COM of the backpack relative to the reference corner. The origin of the force plate was located in the geometric center of the plate. The reference corner of the holder was always placed in the lower left quadrant of the force plate when determining the COM position in the xy, xz, and yz planes of the holder and the composite. The following three equations were used to determine the x, y, and z components of the backpack COM with respect to the reference corner of the holder:

$$x_p = (M_c x_c - M_h x_h) / M_p \tag{1}$$

$$y_p = (M_c y_c - M_h y_h) / M_p \tag{2}$$

$$z_p = (M_c z_c - M_h z_h) / M_p \tag{3}$$

where M_c, M_h, M_p are the mass of the composite, holder, and backpack, respectively, x_c, y_c, and z_c are the distances (x, y, and z component) the composite COM was from the reference corner of the holder, and x_h, y_h, and z_h are the distances (x, y, and z component) the holder COM was from the reference corner of the holder.

The sensitivity of the force plate for the vertical force (F_z) channel has been reported by the manufacturer to be 0.08 micro-volt/volt/N (AMTI, 1991). With the amplifier gain set at 4000 and the excitation voltage equal to 10 volts, the output level for a 60-kg load would equal 1.88 volts and, with a 7-kg load, the output level would equal 0.22 volts. The accuracy of the force plate was factory tested at a low limit of 27.27 kg, which yielded a 1-mm error in center of pressure measurement (ATMI, Personal Communication, June, 2001). In addition to this test, we tested the error with objects weighing 7 kg and found a maximum 8-mm error in COP measurements. Placing the 7-kg object in different marked positions in different quadrants of the force plate and measuring the COP yielded values that had a range of differences from 2 mm to 8 mm. These differences are due to the low output level of the plate.

An 8-mm error in COP measurements was assumed. This error was found to be acceptable in the determination of the COM of test parts and in the determination of MOI values. As an example of the impact of the error, assuming the COM of a 7-kg test part had an error of 8 mm, the MOI would change by only 0.000448 kgm^2.

2.5 Moment of Inertia Relative to Backpack COM

The x-, y-, and z-axes passing through the COM of the backpack and parallel to the coordinate axes of the reference corner of the holder were chosen as the coordinate axes for the MOI measurements. The MOI of a backpack about the x-, y-, and z-axes was designated as I_{xx}, I_{yy}, and I_{zz}, respectively. The products of inertia (I_{xy}, I_{xz}, and I_{yz}) were also measured to obtain the complete inertia tensor.

A Moment of Inertia Instrument (Model XR250, Space Electronics, Inc., Berlin, CT) was used to determine the inertia tensor of the backpack. This instrument, shown in Figure 3, consists of an inverted torsion pendulum that oscillates in a rotational manner. The measuring of the exact period of oscillation of the torsion pendulum is accomplished through a counter that interprets the outputted TTL signal from the device. LabVIEW Version 6*i* (National Instruments, Austin, TX, USA) was used to develop the program to compute the inertial properties of the backpack using the equations described below.

A customized aluminum interface platform was constructed and fixed to the MOI device to allow for the most efficient placement of the composite. The MOI platform interface and dimensions and the force plate interface and dimensions were identical. Once the COM position was determined on the force plate for each plane (xy, xz, yz), the composite was placed in the same position on the interface platform fixed to the MOI device. The placement of the composite was such that the axis of rotation of the MOI device passed through the COM of the composite in each plane, permitting the acquisition of the MOI about the x-, y-, and z-axes. Standardized instructions were then followed to operate the device to obtain the MOI.

The total time for one complete cycle is the period of the oscillation. The total system MOI can be given by:

$$I_T = CT^2 \tag{4}$$

where I_T is the total system MOI, C is the calibration constant of the instrument, and T is the period of oscillation in seconds.

The calibration constant was determined by using a calibration weight provided by Space Electronics Incorporated. The exact MOI of the calibration weight was engraved on the weight and allowed for the calculation of the calibration constant from the following equation:

$$C = I_{cw}/(T_c^{\,2} - T_o^{\,2}) \tag{5}$$

where I_{cw} is the calibration weight MOI, T_c is the period with the calibration weight mounted on the instrument, and T_o is the period with the weight removed. The procedure to determine the calibration constant was followed before the start of the study.

With the calculation of the calibration constant, the total system MOI (I_T) could be determined and could be expressed as the combination of the platform MOI (I_{pl}), the holder MOI (I_h), and the backpack MOI (I_p):

$$I_T = I_{pl} + I_h + I_p \tag{6}$$

In order to determine the components that make up the total MOI, and specifically the MOI of the backpack about the axis that runs through its center of mass, the parallel-axis theorem was utilized. The parallel-axis theorem states that the moment of inertia about any axis (I) that is parallel to and a distance d away from the axis that passes through the center of mass is given by:

$$I = I_{CM} + Md^2 \tag{7}$$

where I_{CM} is the MOI about the COM and M is the mass (Serway, 1990).

Since the platform is symmetrical, the COM of the platform is located in the geometric center of the plate directly over the axis of rotation of the MOI device. Therefore, the d^2 term in the parallel-axis theorem is zero and

$$I_{pl} = I_{CMpl} \tag{8}$$

The MOI of the holder (I_h) is given by

$$I_h = I_{CMh} + M_h d_h^{\,2} \tag{9}$$

where I_{CMh} is the MOI of the holder about the axis that passes through the COM of the holder, M_h is the mass of the holder, and d_h is the distance the COM of the holder was displaced when the COM of the composite was placed over the axis of rotation.

The MOI of the backpack (I_p) is given by

$$I_p = I_{CMp} + M_p d_p^{\,2} \tag{10}$$

where I_{CMp} is the MOI of the backpack about the axis that passes through the COM of the backpack, M_p is the mass of the backpack, and d_p is the distance the COM of the backpack is from the axis of rotation.

Substituting equations 8, 9, and 10 into 6 permits the calculation of I_{CMp} and gives the following equations for the backpack MOI about the x-, y-, and z-axes, respectively:

$$I_{xx} = I_{CMpxx} = I_T - I_{pl} - I_{CMhxx} - M_h d_{hx}^{\,2} - M_p d_{px}^{\,2} \tag{11}$$

$$I_{yy} = I_{CMpyy} = I_T - I_{pl} - I_{CMhyy} - M_h d_{hy}^{\,2} - M_p d_{py}^{\,2} \tag{12}$$

$$I_{zz} = I_{CMpzz} = I_T - I_{pl} - I_{CMhzz} - M_h d_{hz}^{\,2} - M_p d_{pz}^{\,2} \tag{13}$$

To obtain the products of inertia (I_{xy}, I_{xz}, I_{yz}), a custom made aluminum cradle, similar to that used by Albery, Schultz, and Bjorn (1998), was utilized. The MOI about the noncardinal axes in the xy, xz, and yz planes ($I_{\alpha\alpha}$, $I_{\beta\beta}$, and $I_{\gamma\gamma}$, respectively) was needed for the calculations of the products of inertia. The $\alpha\alpha$, $\beta\beta$, and $\gamma\gamma$ axes were oriented 45 degrees from the chosen coordinate axes. Therefore, the cradle was designed to hold the composite at a 45-degree angle from its chosen coordinate axes, as illustrated in Figure 3. The cradle and holder were considered one fixture, and the above COM and MOI determination procedures were followed. Once $I_{\alpha\alpha}$, $I_{\beta\beta}$, and $I_{\gamma\gamma}$ were determined, the products of inertia were computed using the following equations:

$$I_{xy} = (I_{xx} + I_{yy} \tan^2\alpha - (1+ \tan^2\alpha)\, I_{\alpha\alpha}) / 2 \tan\alpha \tag{14}$$

$$I_{xz} = (I_{xx} + I_{zz} \tan^2\beta - (1+ \tan^2\beta)\, I_{\beta\beta}) / 2 \tan\beta \tag{15}$$

$$I_{yz} = (I_{yy} + I_{zz} \tan^2\gamma - (1+ \tan^2\gamma)\, I_{\gamma\gamma}) / 2 \tan\gamma \tag{16}$$

where α is the angle between the x and $\alpha\alpha$ axes, β is the angle between the x and the $\beta\beta$ axes, and γ is the angle between the y and the $\gamma\gamma$ axes (Hinrichs et al., 1982). With the composite placed in the cradle, α, β, and γ are all 45 degrees. If the chosen axes correspond to the "principal axes of inertia", the products of inertia (I_{xy}, I_{xz}, and I_{yz}) vanish, and the terms describing the MOI about the x-, y-, and z-axes (I_{xx}, I_{yy}, and I_{zz}) are the only terms that need to be considered.

Fig. 3. Products of inertia measurement of ALICE fixed in the aluminum cradle located on the MOI device.

3. RESULTS AND DISCUSSION

Our results indicate that the backpack fabricated by Obusek et al. (1997) did not capture the full range of COM and MOI values represented among Soldier-packed combat loads. The range of the MOIs of the Soldiers' packs (Airborne: 0.302 kg·m^2 – 1.979 kg·m^2; Light Infantry: 0.143 kg·m^2 – 1.811 kg·m^2) were larger than the range for the fabricated backpack (0.431 kg·m^2 – 0.882 kg·m^2). The MOIs about the x-, y-, and z-axes and their products of inertia for the fabricated pack and for the Soldiers' packs are shown in Table 1. The COMs of the Soldiers' packs are also located further away from the back compared with the COMs for the fabricated backpack (Figure 4).

Although laboratory research conducted with the backpack fabricated by Obusek et al. (1997) has revealed benefits in terms of energy efficiency and body stability of locating the COM high and close to the back, this positioning of the load may be unrealistic or impossible for Soldiers to achieve, given the equipment they must carry and their mission requirements. The comparisons of the MOIs of the fabricated pack and the Soldiers' packs tell a similar story. The inertial values for the fabricated backpack about all axes are lower than the values for the Soldiers' packs (Figures 5 and 6). Additionally, our results show that the packs with the largest MOI are not necessarily the packs with the greatest mass. Examples are an assistant mortar gunner who had the lowest pack mass, but a proportionally large MOI, and an ammo bearer for the M240 machine gun who had a large pack mass, but a proportionally low MOI (Figure 5).

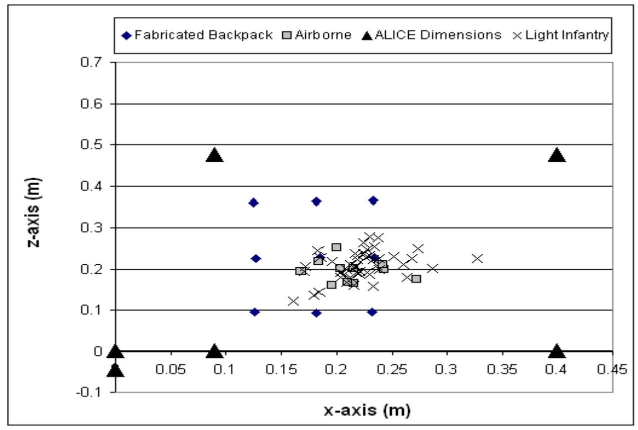

Fig. 4. COM of backpacks in XZ plane by squad positions.

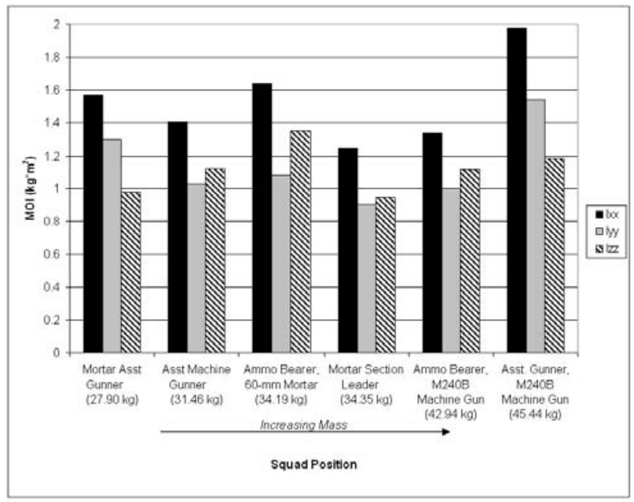

Fig. 5. Mass and MOI of backpacks by selected squad positions.

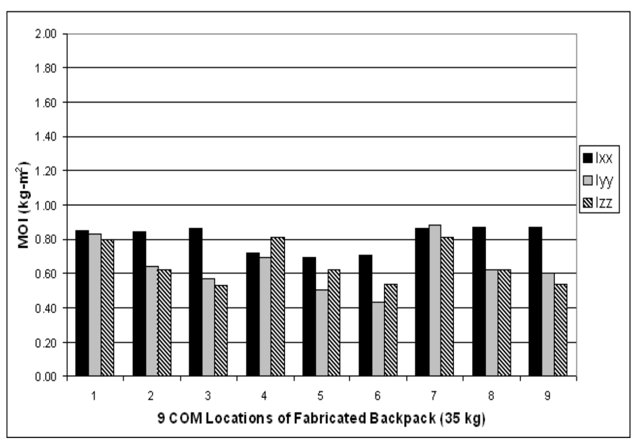

Fig. 6. Mass and MOI of fabricated backpack at 9 unique COM locations.

A preliminary dimensional analysis was developed which showed which groupings of the physical variables were needed in order to create a functional relationship between the dimensionless groupings and Soldier performance. Once the details of this relationship are determined from the experimental data, the results can be applied to these data to determine which groupings of physical properties have the greatest effect on Soldier performance. The insights obtained from this analysis will be applied to the development of a load carriage packing model that will be optimized for terrain and mission requirements, as well as serve as an instructional tool for Soldiers.

4. SUMMARY

Previous research studies confined to the laboratory captured only a partial picture of the actual inertial properties of Soldiers' loads. Data acquired in a field study were used to determine the boundary conditions of the inertial properties of loads actually packed by Soldiers. In future laboratory research on Soldier load carriage performance, we recommend the loads be configured to replicate the physical properties of Soldier-packed loads, as described in this study, thereby increasing the validity of the laboratory work. Future efforts must also include field measurement of the inertial properties of the MOLLE load carriage system, the U.S. Army carrying equipment currently being issued. Field and laboratory research results will be applied in the development of load packing modeling software for enhanced Warfighter performance.

REFERENCES

Albery, C.B., Schulz, R.B., and Bjorn, V.S., 1998: Measurement of whole-body human centers of gravity and moments of inertia, *SAFE*, **28** (2), 78-88.

AMTI, 1991: *Instruction manual Model OR6-5 Biomechanics Platform* (Brochure), Watertown, MA: Author.

Department of the Army, 1990: *Foot marches* (Field Manual 21-18), Washington, DC: Author.

Greenwood, D.T., 1965: *Principles of dynamics,* Englewood Cliffs, NJ: Prentice Hall.

Hinrichs, R.N., Lallemant, S.R., and Nelson, R.C., 1982: *An investigation of the inertial properties of backpacks loaded in various configurations* (Tech. Rep. NATICK/TR-82/023), Natick, MA: US Army Natick Research and Development Laboratories.

Martin, P.E., Hinrichs, R.N., Shin, I., and Nelson, R.C., 1982: *Volume IV. A mathematical model of the inertial properties of a carrier-backpack system* (Tech. Rep. NATICK/TR-82/022), Natick, MA: US Army Natick Research and Development Laboratories.

Norton, K., Hasselquist, L., Schiffman, J., LaFiandra, M., Psicitelle, L., and Bensel, C., 2003: *Inertial properties of an external-frame backpack device* (Tech. Rep. NATICK/TR-03/020), Natick, MA: US Army Soldier Systems Center..

Obusek, J.P., Harman, E.A., Frykman, P.N., Palmer, C.J., and Bills, R.K., 1997: The relationship of backpack center of mass location to the metabolic cost of load carriage [Abstract], *Med. Sci. Sports Exerc.*, **29**, S205.

Serway, R.A., 1990: *Physics for scientists and engineers,* Philadelphia, PA: Saunders College Publishing.

Synge, J.L., and Griffith, B.A., 1942: *Principles of mechanics,* New York, NY: McGraw-Hill.

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Table 1. MOIs About the X-, Y-, and Z-axes and Products of Inertia for the Fabricated Pack and the Soldier Packs

Fabricated Backpack COM Position (35 kg)	**Ixx**	**Iyy**	**Izz**	**Ixy**	**Ixz**	**Iyz**
1	0.8487	0.8267	0.7960	0.0229	0.2478	-0.0614
2	0.8410	0.6448	0.6184	0.0362	0.1993	-0.0519
3	0.8615	0.5677	0.5292	0.0714	0.1640	-0.0338
4	0.7198	0.6949	0.8083	0.0108	-0.0062	-0.0200
5	0.6951	0.5044	0.6200	0.0091	-0.0025	-0.0078
6	0.7122	0.4310	0.5350	0.0313	0.0335	-0.0144
7	0.8623	0.8824	0.8121	0.0182	-0.2906	0.0294
8	0.8697	0.6204	0.6231	-0.0161	-0.2120	-0.0112
9	0.8687	0.6058	0.5348	0.0551	-0.1264	0.0217
Soldier-Packed Combat Loads	**Ixx**	**Iyy**	**Izz**	**Ixy**	**Ixz**	**Iyz**
Mortar Asst. Gunner (27.90 kg)	1.8109	1.6001	0.9763	0.0200	0.0803	0.4021
Asst. Machine Gunner (31.46 kg)	1.5719	1.2276	1.3810	-0.0494	0.1690	0.1898
Ammo Bearer 60-mm Mortar (34.19 kg)	1.6387	1.0835	1.3521	-0.2125	0.0019	-0.1857
Mortar Section Leader (34.35 kg)	1.1239	0.8738	0.7948	-0.0880	-0.0034	0.0551
Ammo Bearer M240B Machine Gun (42.94 kg)	1.3410	1.0035	1.1192	-0.2994	-0.1661	0.0537
Asst. Gunner M240B Machine Gun (45.44 kg)	1.9787	1.5406	1.1859	0.0027	-0.2526	0.0875